Perceptual differences of aromas delivered through the orthonasal and retronasal routes

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Abstract:

Aroma can be perceived through two routes: orthonasal (through the nose) and retronasal (through the mouth). The stimuli elicit signals that eventually reach the same receptors in the olfactory epithelium. However, previous studies suggest there is a perceptual difference between the two routes although the results are inconclusive. In this study, a matching paradigm was designed to control for memory bias and isolate the potential perceptual difference between aroma delivery routes. Panelists performed four matching paradigms of four different strawberry flavors (candy, woody, ripe, and green). The similarity of the four strawberry flavors required panelists to profile each sample to identify acute differences. This increased the cognitive demand required to complete the match. Subjects were given the four strawberry reference standards and told to either smell the sample orthonasally or taste it retronasally. Subjects then matched each reference to one of the four other blind-coded samples by either smelling or tasting congruently (same method) or incongruently (different methods). The retronasal samples consisted of 30 mL aqueous solutions in 2oz black sample cups, while the orthonasal samples consisted of 10 mL aqueous solutions in a capped glass vial wrapped in aluminum foil to minimize visual differences. When matching the reference to unknown samples using congruent evaluations, the panelists performed similarly in the orthonasal and retronasal tests ($p=0.450$) indicating they could correctly identify matching flavors. Performance significantly decreased when performed incongruently ($p<0.002$), suggesting there is truly a difference in perception when the same aromas are delivered via different routes. More knowledge regarding how people perceive aromas and flavors, and how these stimuli relate to one another, will enable the food industry to better optimize the sensory properties of foods and beverages.

Introduction

Food products consist of several attributes that contribute to the overall acceptance of the product: aroma, taste, texture and appearance. When it comes to aroma and taste, they appear to be connected. If you walk into a room and smell something appealing, you are going to expect to also enjoy the taste. Similarly, if it smells terrible you will expect an aversion to the taste (Rozin 1982). However, the basis of this study is whether those senses are as connected as previously believed. Whether, depending on how the aroma is delivered to your olfactory epithelium, you will perceive that stimulus differently. Recent studies investigated the Duality of Smell, a theory in which the olfactory perception is route dependent. Differences in perception arise whether the stimulus is delivered through the nose orthonasally, from the external world, or through the mouth retronasally, from within the body (Rozin 1982). However, results have been inconclusive as to whether the distinction is significant or not.

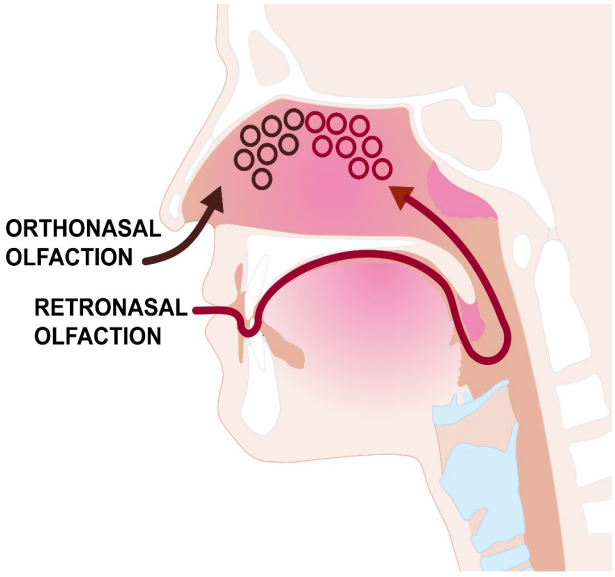

Figure 1. Directional differences of orthonasal and retronasal aroma perception

One study trained the panelists on the aroma of four different soups or juices through the orthonasal route. Once they demonstrated accurate aroma recall, they tested their ability to correctly identify the aromas when presented both orthonasally and retronasally. First, the panelist's performed a routine memory task to identify the soups or juices orthonasally. Following this the panelists completed the same task retronasally. Although the flavors were distinctively different, the panelists had difficulty identifying them across the different routes. (Rozin 1982). However, due to the study design, it is difficult to determine whether this was due to an actual perceptual difference or the memory bias incorporated with the study. Another study delivered the stimuli directly to the anterior nasal cavity or epipharynx through an air-dilution olfactometr, eliminating the act of smelling or swallowing the stimuli to identify the flavor. The panelists were trained prior to perform a certain breathing technique that avoided respiratory airflow through the orthonasal route in order to isolate the retronasal route. This study found that

performance was higher for identification in the orthonasal route than the retronasal. Additionally it found that panelists had a higher threshold in the orthonasal route (Heilmann and Hummel 2004). Yet this method eliminated the act of consuming the product, disregarding the potential effect that normal consumption might have on perception. It lacks the ecological validity of smelling or eating food, and the natural perceptions that come with it.

The aim of this study was to investigate this perceptual difference in a way that will help control for memory bias while maintaining the ecological validity of perceiving aromas. Four strawberry aromas were chosen that are distinguishable from one another but similar enough that it forced the panelist to profile each one to determine the difference, further isolating the routes. The panelists performed four different matching paradigms, two utilizing congruent (same) sample methods and two utilizing incongruent (different) tasting methods. The determination of a perceptual difference will benefit sensory scientists in the industry in better training their panelists to analyze products. Training people based on one route of perception is not effective in analyzing a product in another if their profiling of the characteristics does not match. Better understanding of how people perceive aromas will benefit the industry in optimizing products.

Hypothesis:

It is hypothesized that the ability to match the correct stimulus to the reference sample becomes more difficult when delivered across different routes. It is believed the routes elicit a different perception of the aromas making it more difficult to match them.

Procedure/ Methods:

Panelists:

30 untrained subjects were recruited through the Ohio State University Consumer Sensory Testing Center's recruitment database. The panelists claimed to be in good health with no known taste, smell or memory deficits. The test was conducted through Compusense, a sensory acquisition software (Compusense Inc. Canada).

Materials:

Four strawberry flavors (candy, woody, ripe and green) were selected (Mane Flavors, Cincinnati, Ohio) and (Wild Flavors, Erlanger, Kentucky) that are differentiable from one another, yet similar enough it forced the panelist to profile them to determine acute differences.

The flavors were diluted in distilled water at isointense levels across the flavors and delivery routes (Table 1). The levels were selected by a preliminary panel (n=10) and were described to be at moderately intense. The orthonasal samples (10 mL) were placed in individual capped glass vials and wrapped in aluminum foil to eliminate visual effects. The retronasal samples (30 mL) were served in black 2oz cups to eliminate visual effects.

Table 1: Isointense concentration levels across each flavor and delivery route

	Stimuli	**Orthonasal Concentration Level**	**Retronasal Concentration Level**
Flavors	Strawberry A	0.33%	0.40%
	Strawberry B	0.20%	0.35%
	Strawberry C	0.25%	0.35%
	Strawberry D	0.30%	0.25%

Procedure:

The panelists were provided with each sampling method separately, which included two congruent (same) methods, and two incongruent (different). The congruent sampling methods acted as the control of the study. In the congruent orthonasal condition, panelists were instructed to smell a reference sample through their nose and then match it to one of the four unknowns using the same method. The congruent retronasal condition instructed panelists to swallow the reference sample and then find the match from four unknowns by also swallowing. The incongruent orthonasal-retronasal condition instructed them to smell the reference sample orthonasally and then find the match from the four unknowns retronasally and then vice-versa for the incongruent retronasal-orthonasal condition. For each testing method they were provided with each of the four strawberry flavors as reference samples, completing the matching task a total of 16 times. The reference samples were labeled as Strawberry A, B, C and D in order to limit the information the panelists have for the flavors. The samples were labeled with 3-digit blinding codes, randomized and counterbalanced. The similarity of the four strawberry flavors required the panelists to profile each sample in order to identify the acute differences. The

panelists were allowed to reassess each sample as much as needed in order to confidently make their decision.

Data Analysis:

Binomial tests were used to determine if a significant number of panelists performed better at determining the matching flavors for the congruent tests versus the incongruent. In order to determine if route of delivery significantly affected people's ability to make a correct match, McNemar's test was used to evaluate the distribution of responses.

Results and Discussion

The "Duality of Smell" hypothesis was further tested with this study, evaluating whether a perceptual difference exists when stimuli are delivered through the different routes: orthonasal (ON) and retronasal (RN). The panelists' performance on matching the incongruent sampling methods was compared to their performance on the congruent, which acted as the control. As shown in Table 2, a significant majority of panelists demonstrated their ability to match the samples when delivered through the same route (congruent), however when delivered through different routes (incongruent) panelists were not able to perform as well. This indicates that the profile they established for the reference sample, whether it was delivered orthonasally or retronasally, was not comparable to the profile they established when delivered through the differing route. Despite the fact that they were able to utilize that profile to compare when the stimuli were presented through the same route. These results are significant ($p<0.002$) in suggesting that there is a perceptual difference between the two routes of delivery.

Table 2: Number of individuals who performed better in the respective sessions across each cognitive strategy

	Strawberry (N=30)
Congruent sessions	19
Incongruent sessions	3
Neither	8

As shown in Figure 1, when comparing between the congruent sampling methods, ON-ON and RN-RN, there is not significant difference (ON-ON: 65% and RN-RN: 60%; $p=0.450$),

and similarly when comparing between the two incongruent tests (ON-RN: 53% and RN-ON: 46%; p=0.260). However, there was a significant difference between the ON-ON and both of the incongruent tests (ON-RN: p=0.05 and RN-ON: p=0.004), while the RN-RN congruent was only significantly different from the RN-ON condition (p=0.039), but not the ON-RN (p=0.320). People tend to be more sensitive through their orthonasal route, leading to the expectation that they would perform better in the orthonasal congruent test than the retronasal. However, potentially due to the preparation of isointense concentrations (Table 1) across the two routes, the two congruent conditions were not significantly different. The lack of significance in these routes, when delivered congruently, suggests that they should both be significantly better than the two incongruent conditions. This was not the case though; the RN-RN route was only significantly higher than the RN-ON incongruent. This could be a result of the general higher sensitivity in the orthonasal route, even though it is minimal in this study.

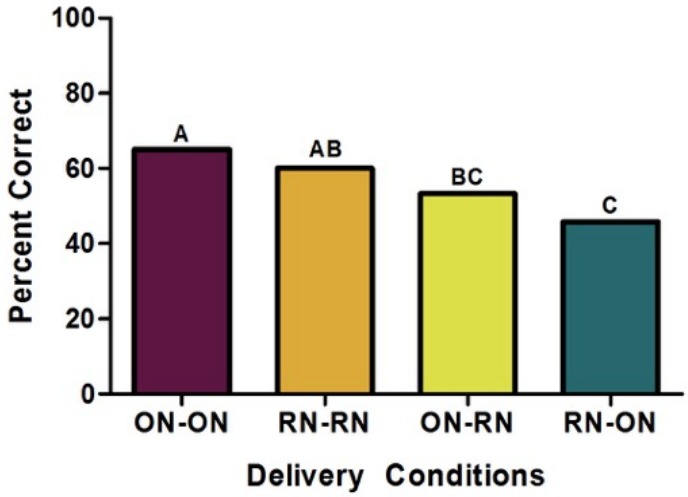

Figure 1: Percent correct for each sampling method. Letters above the bar indicate significant difference between each session as determined by the McNemar's test.

When selecting the stimuli for this study, the four varieties of strawberry were selected in order to create a difficult task that would truly test the panelists' ability to determine the matches. Figure 2 displays the number of panelists that answered the respective number of correct matches for each aroma delivery condition. Overall the

distribution of this graph is fairly centered, with a majority of panelists obtaining roughly two of the four strawberries correct. This indicates that not many people were able to answer a majority correct for each condition. Looking closer merely 6 panelists of 30 were able to answer all four of the ON-ON sampling condition, and not a single person was able to correctly match all four of the RN-ON sampling condition. Only 17 panelists were able to answer half of the RN-ON samples correctly. This graph represents the difficulty of the task, regardless of the method of delivery the panelists struggled profiling the strawberries in order to successfully determine a majority of the matches. This challenge ensured the further isolation of the routes and helped emphasize the perceptual difference.

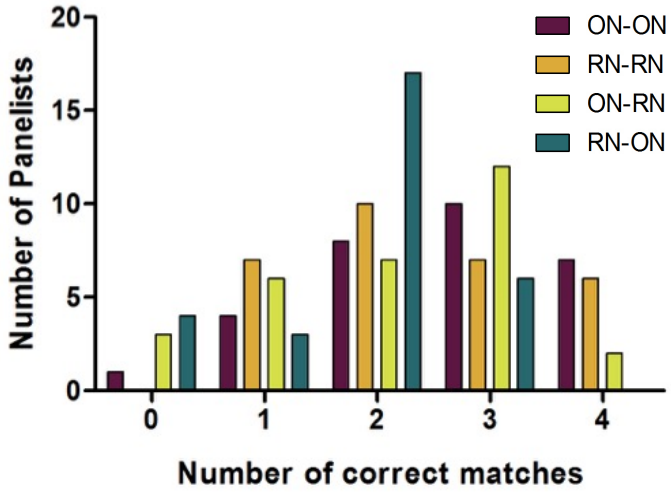

Figure 2: Distribution of number of subjects across correctly identified matches.

Future Work

This study provided significant results in the determination of a perceptual difference between the routes of deliver, orthonasal and retronasal. However, further investigation could be done repeating this study adjusting two test parameters: 1) increasing the complexity of the solutions; 2) decreasing the panelist burden associated with sampling numerous solutions. One adjustment involves potentially diluting the flavors in a sugar solution, rather than distilled water, to provide greater complexity that would more closely mimic a typical eating experience such as flavored water. By doing this we can further determine if a perceptual difference remains

when introducing another confounding variable, sucrose, in this instance. The study also consisted of a significant number of samples, which could have caused the panelists to become fatigued by the end of the test. Effects of this potential fatigue could be reduced by either breaking the test up over two days, or by giving them a break after two sampling conditions. However, this adjustment runs the risk of different variables affecting the panelists' perception between days, and panelists just wanting to finish the study and not take a break. Overall, the parameters of the test were successful but these adjustments could be considered.

Conclusion

This study was used to determine if there is a difference in the perception elicited by the two different routes of aroma: orthonasal and retronasal. These routes have a significant impact on our view of food, but without further research their correlation could be mistaken. A matching paradigm was utilized to isolate the routes and establish if it is more difficult to determine the match when the delivery routes are different. Panelists were not able to perform as well when forced to utilize both routes in order to determine the match in comparison to utilizing the same route. From these results we were able to conclude that there is a perceptual difference between the two routes of delivery, confirming our hypothesis. This information can be used to benefit the training of panelists for sensory testing by increasing our overall knowledge of how people perceive food.

References:

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